RELIABILITY-BASED DESIGN OPTIMIZATION OF STRUCTURAL DURABILITY UNDER MANUFACTURING TOLERANCES

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In structural design for durability and safety, the primary concern is to reduce structural fatigue damages due to transient dynamic loadings applied during the service life of mechanical systems. However, due to uncertainties in dimensions and material properties due to the manufacturing process of the structural component, prediction of the fatigue life of the structural component is quite indeterministic. By taking such uncertainties into consideration, a probabilistic design approach for structural durability and safety provides a reliable design with required fatigue life span. The objective of this paper is to develop and apply the Reliability-Based Design Optimization (RBDO) process for structural durability to obtain a highly reliable design under fatigue life constraints.

A durability analysis of a mechanical system that predicts fatigue failure of a structural component due to damage accumulations is a compute intensive multidisciplinary simulation process, since it requires an integration of several computer-aided engineering tools, such and multibody dynamic analysis, finite element analysis, and durability analysis, and large amount of data communication and computation. In addition, the RBDO process that requires expensive reliability analyses for evaluation of probabilistic fatigue life add computational intensity further for industry scale problems. For evaluation of probabilistic constraints in the RBDO process, the performance measure approach that employs the Hybrid Mean Value (HMV) first-order reliability method is numerically shown to be very efficient and stable. Due to the fact that uncertainty propagation to structural fatigue under transient dynamic loading is not only numerically complicate but also computationally expensive, it is a challenging task to integrate the RBDO process for durability optimization. This paper presents an integrated CAD-based process to effectively carry out RBDO for structural durability.

In addition, in design optimization for fatigue life, the number of constraints could be very large if fatigue life constraints are defined on every point of the structural component. To make the problem computationally tractable, in structural durability analysis, a preliminary fatigue life analysis for a crack initiation is carried out to detect critical spots with short fatigue life to define design constraints. Refined durability analysis is then carried out at these critical spots to obtain accurate fatigue life. Various model uncertainties such as geometric tolerance and material properties are taken into account to appropriately predict uncertainties of the structural durability through the process of advanced reliability analysis. In summary, the envisioned CAD-based process is developed, by integrating a proposed effective RBDO method with systematic durability analysis, with emphasis on numerical efficiency and accuracy. A durability model of Army M1A1 tank roadarm is employed to demonstrate numerical feasibility and efficiency of the integrated CAD-based process for RBDO of structural durability.

References

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